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Operating Activities of Energy Companies in the Context of Crude Oil Risk and its Impact on the Polish Power Exchange

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Abstract

Different factors have significant impact on the development of the Polish Power Exchange and the volatility of electricity contracts prices, which are quoted on this part of energy market. The electricity prices are strongly influenced by such determinants as: the level of turnover volume, fuel prices, weather conditions, the CO2 emission allowance prices, political situation, the changeability of the energy demand level. The purpose of this paper is to examine and compare the volatility behaviour of world crude oil prices and electricity prices established on the Polish Power Exchange (POLPX) in the turbulent period, which covers the subprime financial crisis, geopolitical crisis, and changes in the rules of the European Union's energy policy. The background for the empirical research is a comparative analysis of business strategies of Polish energy companies and their adaptation to the factors that in the significant way influence the development of energy sector in Poland.

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Keywords: Crude oil risk; Electricity prices; Polish Power Exchange; Markov switching model; Energy companies.

Introduction

The Polish Power Exchange (POLPX) began its operation in December 1999 and half a year later the Day-Ahead Market was started. The Day Ahead Market enables an initial adjustment of electricity volume to the changing demand of wholesale market subjects and determines benchmark electricity prices for other contracts concluded on the wholesale electricity market in Poland. This market participants include among others electricity producers and sellers, electricity turnover partnerships, non-tariff energy buyers trading it directly on the spot market or through

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brokerage houses. Because some energy companies conduct aggressive strategies and sells most of the energy produced through the POLPX, hence, it is important to present the operations activities of energy companies and the risk arising from the volatility of electricity prices in order to ensure them profitable operation**.** The purpose of this paper is to examine and compare the volatility behaviour of world crude oil prices and electricity prices established on the Polish Power Exchange in the turbulent period, which covers the subprime financial crisis, geopolitical crisis, and changes in the rules of the European Union's energy policy. The first part of the article includes the identification of operating activities of energy companies in the field of energy sales and risk factors in the crude oil market and the Polish Power Exchange. Then we analyse the volatility dynamics of following time series: the West Texas Intermediate crude oil (WTI) prices and Brent crude oil (Brent), which are denominated into PLN and the electricity prices quoted on the Day-Ahead Market of Polish Power Exchange in the period of 01.01.2002-30.11.2014. Empirical analysis is connected with construction of univariate Markov switching heteroskedasticity models with GARCH structure for each of analyzed variables. The Markov regime-switching model can detect switches in the volatility regimes of the returns and measure average duration of each variables in particular volatility states. These findings help us to evaluate the synchronization of occurrence of higher price risk periods on crude oil market and on the Polish Power Exchange.

1. Operating activities energy companies

The specificity of the market in which energy companies operate causes that are directly related to the state of the economy - economic growth is associated with increased consumption of the electricity. Energy companies produce a product that is consumed independently on the turbulence in the economy and is characterized by relatively low elasticity of demand (Osadczuk, 2011). Energy companies in Poland are large capital groups leading diversified activity in all key segments of the energy market, i.e. in the extraction of raw materials, manufacturing, distribution and trading of electricity and heat, as well as centers of the guidance and the control and the customer service. Analysing strategic documents of the energy companies should be noted that all of them regularly monitor market and regulatory environment. Their business strategies are adapted to the factors which in the most significant way influence the energy sector, i.e. national and EU regulations concerning the functioning of the energy sector, and in particular the energy-climate package, the Law on Energy Efficiency, the Directive on Energy Efficiency. The companies plan to increase investment in operations activities, primarily in the area of manufacturing, which is reflected in the planned realizations for the construction of new high-efficiency coal-fired power plants and gas pipelines. Companies are also planning to increase the share of low-carbon technologies, i.e. the gas, wind, water and biomass. Choosing a method for producing electricity by the companies is not only a result of access to specific technology, but also dependent on the national and EU laws. In addition, more and more often we can see that these companies apply the principles of economic calculation in decision-making operations. Among Polish companies changes in the structure of electricity generation has been observed in recent years, primarily a significance of units being based on renewable energy sources grows (biomass, wind) with lower participation of units based on solid fuels. Even so, conventional fuels still account for the vast majority in the structure of electricity generation (88.6% in 2012). Currently, the companies are forced to sell the produced energy power through the power exchange. By mid-2010, sales of electricity in approximately 93% was conducted on the basis of bilateral agreements, and the electricity generated by power stations was almost entirely sold on the wholesale market. On the balancing market it was sold about 6-8,4% of energy, and only a small part (0.7%) through power exchange (Grudzinski, 2013). Since 2010 there has been a change in the statutory in the pricing energy and now almost 62% of the electricity (including the Day-Ahead Market and Commodity Forward Instruments Market) is sold through the power exchange. As a result, the Polish market has become a competitive market and largely transparent. Hence, the main relationships between prices of fuels decided the demand for the given fuel and influence on energy prices. If the prices of electricity will be more competitive in relation to the prices on the international market, there is a greater possibility of an increase in exports of energy or production growth, which in turn stimulates the growth of fuel consumption in power plants (Grudzinski, 2013). One of the important factors that affect the electricity price movements are changes in oil prices. There are many factors that directly and indirectly affect the prices of crude oil on world markets. i.e.: supply, demand, inventory levels, investments, disruption in oil supply. Also political factors have a significant meaning in crude oil prices. Unfavorable phenomenon in this market is the high concentration of oil resources in countries characterized by low levels of economic development and socio - political stabilization. Sometimes the internal policies of these countries can be defined as activities whose purpose is to achieve democratic change through non-democratic tools and approaches. Another factor which increasingly has an impact on the price of oil is a speculative investor activity (Kaliski, Jedynak and Bialek, 2011). Political conflicts involving states – crude oil exporters resulted in a reduction of the supply of this fuel, resulting in an imbalance between crude oil supply and increasing demand for this raw material and was shown in changing market prices of crude oil. National energy security issues, including issues of meeting the demand for crude oil, are a priority for governments that do not have direct access to the deposits of this raw material, but also are essential for entrepreneurs whose business is closely linked to the use of oil. Very often these companies as part of the diversification of its operations, are linked to the electricity market and often as the power exchange participants are also exposed to price risk on the commodity market (Wlodarczyk, 2014). Hence they are interested in information about price risk, characterized by crude oil and power energy market.

2. Methodology

In empirical research Markov switching heteroskedasticity models were implemented in order to identify the high-risk periods on oil crude market and electricity market. The general form of p-th order Markov –switching dynamic regression model (MS-AR(p)) is given by the following equations (Doornik, 2013):

$$r_t = \varphi_1(s_t)r_{t-1} + \varphi_2(s_t)r_{t-2} + \cdots + \varphi_p(s_t)r_{t-p} + \varepsilon_t, \;\; \varepsilon_t \sim N(0, \sigma^2(s_t)) \tag{1}$$

where: r_t – logarithmic returns on WTI, Brent prices or logarithmic electricity prices, s_t – non-observable variable modelled as homogenous Markov chain of N states and the matrix of transition probabilities $P = \lfloor p_{i|j} \rfloor_{i,j\in\{0,1,2,\ldots,N-1\}}$, determining the probability of moving endogenous variable from state *j* in period *t* into state *i* in period *t+1,* fulfilling the following stochastic assumptions:

$$\sum_{i=0}^{N-1} p_{i|j} = 1, \qquad p_{i|j} \geq 0 \quad \text{for i, j} = 0,1,\ldots N - 1, \tag{2}$$

$\varphi_i(s_t)$– regime-dependent parameters.

It is worth to underline that **P** matrix elements fulfil the following Markov property (Hamilton, 1994):

$$P(s_{t+1} = i \mid s_t = j, s_{t-1} = k, \ldots, r_t, r_{t-1}, \ldots, r_0) = P(s_{t+1} = i \mid s_t = j) = p_{i|j}\,. \tag{3}$$

Due to the presence of the volatility clustering effect in analysed returns series the GARCH structure was incorporated into Markov switching model, which enables for different behaviour of the volatility process in particular regimes (Hamilton and Susmel,1994). In this paper the following specification of the MS-GARCH(1,1) was estimated (Doornik, 2013)[†]:

$$\varepsilon_t = \sqrt{h_t(S_t)} \cdot \nu_t, \quad \nu_t \sim \mathrm{N}(0,1), \tag{4}$$

$$h_t(S_t) = \sigma^2(S_t) + \alpha_1(S_t)\varepsilon_{t-1}^2 + \beta_1(S_t)h_{t-1}(S_t), \quad \sigma^2(S_t) > 0, \alpha_1(S_t) \geq 0, \beta_1(S_t) \geq 0, \tag{5}$$

[†] In particularly a simpler version of the MS-GARCH model was also estimated, in which only sigma parameter is subject to switching among different regimes, while the others are not time-varying (Doornik, 2013).

where: $h_t(S_t)$ - regime dependent conditional variance of the error term; $\alpha_1(S_t)$ – regime dependent ARCH parameter depicting the reaction of volatility process on new market information; $\beta_1(S_t)$ - regime dependent GARCH parameter measuring the persistence of volatility process.

The most frequently used method of parameter estimation in Markov-switching model is the maximum likelihood method (Hamilton, 1994; Doornik, 2013). In order to determine the proper number of regimes in Markov's switching models one may use regime classification measure (RCM), which was proposed by Ang and Bekaert (2002).

The next step of the analysis is connected with evaluating the similarity between the occurrence of high volatility regimes for Polish electricity market and world crude oil market. So, according to Harding and Pagan (2002) the concordance index (CI) is computed by using the following formula:

$$CI_{ij} = \frac{1}{T}\left[\sum_{t=1}^{T} S_{it}S_{jt} + \sum_{t=1}^{T}(1-S_{it})(1-S_{jt})\right] \tag{6}$$

where S_{it} and S_{jt} denote binary variables that take the value unity in case of high volatility regime and zero - in case of low volatility regime at time *t* for variables *i* and *j* respectively.

3. Empirical results

The electricity prices are strongly influenced by such determinants as: the level of turnover volume, fuel prices, weather conditions, the CO2 emission allowance prices, political situation, the changeability of the energy demand level, available power in the National Electricity System. Therefore we are interested in the issue of the comparison of the occurrence of periods characterized by high price risk in the crude oil market and electricity market. The electricity price behavior on the Polish Power Exchange is described by IRDN index. IRDN is the Day-Ahead-Market Index (PLN/MWh) representing the weighted average price of all transactions on the trading session, calculated for particular delivery date. The highest price change on the Day-Ahead Market was observed on January 2, 2008 (daily price increase of about 202%), December 3, 2014 (daily increase of almost 133%), November 25, 2014 (daily increase of about 127%). Moreover, on November 12, 2008, April 28, July 28, August 4, September 18 and October 30, 2014, the IRDN index value increased by more than 80% a day and the next day IRDN returned to the previous level. This spiky behavior of spot electricity prices is explained in econometric literature (Jong 2006, Nowotarski, Tomczyk & Weron 2013).

For both WTI and Brent crude oil prices[‡] weekly continuously compounded rates of return were computed, according to rules: $r_t=100\cdot\ln(p_{i,t}/p_{i,t-1})$, where $p_{i,t}$ is daily closing price for i-th variable at t week. After that the Markov-switching regressions with GARCH structure are estimated (comp. (1) – (5)) and the periods corresponding to high, medium and low volatility regimes on crude oil market are determined on the basis of smoothed probabilities derived from the best Markov model. According to Daskalakis, Psychoyios & Markellos (2014) approach the logarithmic electricity prices are decomposed into the long-term seasonal component and stochastic component, which is the subject of further modelling. The IRDN series with weekly frequency is deseasonalized by regressing it against a time trend, dummy variables for monthly periodicities and a cosine function for the annual cycle (see Daskalakis, Psychoyios & Markellos, 2014, Nowotarski, Tomczyk & Weron 2013). Due to the presence of volatility clustering and the autocorrelation effects in stochastic components the MS(N)-AR(p)-GARCH(1,1) models are estimated, with N=2 or N=3. The sample period ranges from January 1, 2002 to November 30, 2014. The values of estimated parameters of Markov-switching models with Gaussian innovations distribution are presented in Table 1.

[‡] We convert these prices from USD to PLN using the closing spot USD-PLN exchange rate obtained from Forex market.

Table 1. Estimation of Markov switching model with GARCH structure

Parameter	WTI (N=3)	Brent (N=3)	IRDN (N=3)	Parameter	WTI (N=3)	Brent (N=3)	IRDN (N=3)
Constant (0)	0.275 [0.10]	0.226 [0.15]	4.67e-6 [0.99]	sigma (0)	0.954 (0.25)	0.637 (0.18)	0.007 (0.00)
Constant (1)	-7.396 [0.00]	-6.369 [0.00]	-2.7e-5 [0.96]	sigma (1)	6.398 (7.02)	4.153 (1.07)	0.004 (0.00)
Constant (2)	0.730 [0.89]	2.0538 [0.00]	-0.0007[0.88]	sigma (2)	12.64 (7.99)	0.640 (0.19)	0.021 (0.00)
AR-1 (0)	-0.036 [0.38]	-0.044 [0.29]	-1.86 [0.00]	ARCH-1(1)	0.016 (0.02)	0.043 (0.02)	0.073 (0.04)
AR-1 (1)	-0.716 [0.00]		-1.324 [0.00]	GARCH-1(1)	0.923 (0.04)	0.921 (0.03)	0.77 (0.07)
AR-1 (2)	-0.403 [0.53]		-1.597 [0.00]	ARCH-1(2)	0.0001 (0.40)	0.818 (0.45)	0.073 (0.04)
AR-2 (0)	-	-0.071 [0.09]	-2.50 [0.00]	GARCH-1(2)	0.159 (1.85)	0.000 (0.16)	0.77 (0.07)
AR-2 (1)	-		-1.613 [0.00]	ARCH-1(3)	0.001 (1.15)	0.106 (0.08)	0.073 (0.04)
AR-2 (2)	-		-2.184 [0.00]	GARCH-1(3)	0.454 (1.12)	0.814 (0.13)	0.77 (0.07)
AR-3 (0)	-	-	-2.195 [0.00]	Regime 0 duration / fraction	160.25weeks / 95.39%	149.25 weeks / 88.97%	11.78 weeks / 15.87%
AR-3 (1)	-	-	-1.41 [0.00]	Regime 1	7 weeks / 3.13%	8.25 weeks / 4.92%	25.33 weeks / 68.26%
AR-3 (2)	-	-	-2.315[0.00]	Regime 2	10 weeks / 1.49%	10.25 weeks / 6.11%	8.15 weeks / 15.87%
AR-4 (0)	-	-	-1.193 [0.00]	Jarque-Bera	2.792 [0.25]	1.324 [0.52]	3.592 [0.17]
AR-4 (1)	-	-	-1.760 [0.00]	B-P(25)	34.43 [0.10]	22.15 [0.51]	393.1 [0.00]
AR-4 (2)	-	-	-0.398 [0.00]	ARCH(2)	1.574 [0.21]	0.140 [0.71]	1.812 [0.18]
AR-5 (0)	-	-	-0.382 [0.00]	RCM	0.043	0.581	1.760
AR-5 (1)	-	-	-0.693 [0.00]	CI – high	0.8368	0.8563	
AR-5 (2)	-	-	-1.760 [0.00]	CI – medium	0.8189	0.7904	

Note: p-value in brackets and standard errors in parentheses.

Finally, three volatility regimes have been distinguished in the modelling: low volatility regime - 0 (in the case of crude oil market) and 1 (in the case of Polish electricity market), moderate volatility regime -1(WTI, Brent), 0 (IRDN) and high volatility regime -2. As one can see in Table 1, each of the three regimes is rather stable, as estimated transition probabilities from one to another regime are rather low (below 0.2). The high volatility regime duration is about 10 weeks (WTI, Brent) and 8 weeks (IRDN). However only 1.49% of WTI returns and 6.11% of Brent returns were assigned to this volatility state. In the case of electricity market about 15.87% prices correspond to high volatility regime. On the basis of relatively low values of the RCM measures one can draw a conclusion that each estimated model is able to distinguish which regimes occur at each point in time.

Table 2. Regime classification based on smoothed probabilities

WTI		Brent		IRDN			
Medium volatility regime		Medium volatility regime		Medium volatility regime		High volatility regime	
Period	ASD	Period	ASD	Period	ASD	Period	ASD
03.03.19 – 03.04.30	0.858	02.11.20 – 03.03.12	0.959	02.05.29 – 02.10.16	0.772	02.02.13 – 02.03.13	0.810
04.12.01 – 04.12.01	0.520	03.05.07 – 03.06.04	0.606	03.11.05 – 04.01.07	0.819	02.10.23 – 02.12.25	0.834
08.09.17 – 08.12.10	0.923	04.12.15 – 05.02.09	0.679	05.03.16 – 05.06.01	0.678	05.12.14 – 05.12.14	0.817
		08.12.31 – 09.03.04	0.677	07.06.27 – 07.08.29	0.662	06.10.18 – 06.11.01	0.832
High volatility regime		High volatility regime		10.11.17 – 11.01.19	0.729	07.10.17 – 08.01.02	0.924
Period	ASD	Period	ASD	11.10.19 – 12.01.18	0.960	08.08.20 – 08.12.31	0.966
08.12.17 – 09.02.18	0.980	02.10.23 – 02.11.13	0.872	12.07.18 – 12.08.22	0.637	09.11.18 – 09.12.30	0.810
		03.03.19 – 03.04.30	0.683	13.06.26 – 13.07.24	0.433	11.08.03 – 11.08.03	0.508
		04.11.03 – 04.12.08	0.710	14.02.26 – 14.06.25	0.939	12.01.25 – 12.02.15	0.781
		08.09.10 – 08.12.24	0.934			12.11.07 – 12.12.26	0.950
						13.07.31 – 13.08.14	0.696
						13.10.02 – 13.12.25	0.905
						14.07.02 – 14.11.05	0.767

Note: ASD - Average smoothed probability; Date's format YY.MM.DD

Presented in Table 1 concordance indexes (6) indicate the high synchronization of periods of high volatility occurrence may be observed for the IRDN prices series and both crude oil prices series (0.8368 for WTI and IRDN and 0.8563 for Brent and IRDN).

The high volatility of electricity prices on the DAM corresponds to such events as: the inclusion of costs of carbon emissions into the electricity prices in Poland, the subprime crisis in the United States, the debt crisis in Europe, the Russian-Ukrainian crisis, the beginning of the III Phase of the EU ETS and the accompanying it changes in the regulatory mechanisms of CO2 reduction, the EU climate summit in Brussels. Comparing the moments when the high volatility regime began and finished for each of the returns series (see Table 2) one can indicate some similarities of their occurrence, connected with the impact of subprime financial crisis (2008/2009). Moreover, the high price volatility on crude oil market is also observed in 2003 year, which was caused by the Iraq war (2003). It is worth stressing that Iraq contains a large amount of global oil reserves and this event enlarged the uncertainty on crude oil market.

It is worth stressing that this is the preliminary stage of author's research and all presented models should be subjected to calibration.

Conclusion

The transformations have been challenged in recent years fuel and energy sector make changes to the structure of electricity generation. Efforts to strengthen its position in the market and be competitive requires a major commitment of these companies in their own development. Key for energy companies will be the next few years. The manner in which these companies will change the structure of energy production and adapt to environmental requirements can provide them to be or not to be on the market. On the one hand, their activities require incurring huge financial outlays for modernization processes as well as all new investment projects. On the other hand, a more transparent market for energy through energy exchange is a demanding and prone to numerous risks including the risk of crude oil.

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